ATTACHMENT A
METHODOLOGY

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INTRODUCTION

This Attachment A (Methodology) describes the methodology used in the analysis presented in the report entitled "Task 3: Petroleum Reduction Options". The Task 3 report is part of a larger effort being conducted by the Energy Commission and the Air Resources Board to develop strategies and recommendations to establish statewide petroleum reduction goals.

KEY METRICS

Before discussing the methodology used in this analysis, it is necessary to clarify certain key metrics used throughout the report. These metrics are:

- **Potential Fuel Displacements:** Absolute magnitude and percent of base case on-road fuel demand. Helps define goals for reducing the rate of petroleum use.

- **Present Value of (Direct Non-Environmental) Net Benefits:** Positive values indicate opportunities where consumer benefits exceed losses in government revenues. For the sake of brevity, the shorter version of this term is used throughout the report (present value of net benefits or net benefits).

- **(Direct Non-Environmental) Net Benefits per Gallon of Fuel Displaced:** Indicates society's relative value (savings or cost) for each gallon of fuel displaced. For the sake of brevity, the shorter version of this term is used throughout the report (net benefits per gallon of fuel displaced).

- **Present Value of (Direct Non-Environmental) Net Consumer Benefits:** Positive values indicate opportunities where consumers are better off and where market success is possible. For the sake of brevity, the shorter version of this term is used throughout the report (present value of net consumer benefits or net consumer benefits).

- **(Direct Non-Environmental) Consumer Benefits per Gallon of Fuel Displaced:** Indicates the consumer's relative benefit (positive for savings or negative for cost) for each gallon of fuel displaced. For the sake of brevity, the shorter version of this term is used throughout the report (consumer benefits per gallon of fuel displaced).

GENERAL METHODOLOGY

The staff 's methodology is based on a step-by-step approach, using the following five steps:

1. Collect data or information about each option.
2. Identify and apply an appropriate method or tool to analyze each option.
3. Calculate the petroleum reduction compared to the base case.
4. Determine the costs and benefits associated with the option.
5. Evaluate and compare the various options using common metrics.

Although the methodology for Group 2 used the same general approach, the actual comparison method differed. A detailed description of this variation is discussed below.

Step 1. Collect Data or Information

Appropriate data or information was needed to characterize the measure and provide input for the analysis. An important part of this step was identifying timing of the measure, expected market penetration rates and cost of implementation. In some cases staff used consultant information and in other cases staff developed independent estimates. Staff either collected new data related to costs and estimated fuel savings or updated data from previous analyses.

Step 2. Identify and Apply an Appropriate Method or Tool

Staff used one of two approaches to conduct the analysis of each option. The CALCARS model, which provided the gasoline base case forecast for light duty vehicles, was used for analysis of broad measures affecting pricing. For other fuel economy options, staff used the FUTURES spreadsheet model (see Option 1A, Improved Vehicle Fuel Economy, for a description of this model). The CALCARS model was also used to estimate the market share of different vehicle classes that comprise the projected light-duty vehicle population by model year. This information was then used in the FUTURES model. For other measures staff developed scenarios to directly estimate the petroleum savings, program and vehicle costs, and value of fuel savings.

CALCARS Model. The CALCARS model forecasts future travel and energy demand for California's fleet of light duty vehicles. Based on vehicle attributes (e.g., fuel cost per mile), the model predicts vehicle ownership and use. The model can forecast the fuel demand under a proposed option and explicitly quantify the change from the base case in California travel and fuel use resulting from the option's implementation. An option's petroleum reduction is determined by subtracting its demand outcome from the forecast for the base case.

Scenarios. For options not within the analytic framework of the CALCARS model, the evaluation method used was based on a scenario approach. Staff developed a common strategy needed to increase market penetration for a variety of fuel displacement options, which assumed:

- Advancement in technology performance under mature market conditions.
- Reductions in costs due to technology advancement or commercial production levels.
- Resolution of market barriers, such as providing adequate and convenient fueling infrastructure.
- Differences in costs and impacts for mature technologies, when compared to technologies that require long-term research and development to reach commercial deployment.
- Other plausible market conditions or outcomes.

Step 3. Determine the Petroleum Reduction Compared to Base Case

The staff determined the petroleum reduction due to the option based on the assumed efficiency improvement, reduction in vehicle miles traveled (VMT), or the level of fuel substitution when compared to the base case forecast. The total cost of implementing the option for the consumer and program costs for the state were then compared to the value of the fuel savings to determine the direct net benefit of the option (see discussion in Step 4 below).

Step 4. Determine the Costs and Benefits

Where possible, staff determined the present value of net benefits of the options for three time periods: 2002-2010, 2002-2020 and 2002-2030 using an annual discount rate of 5 percent. The 5 percent rate reflects the discount rate applicable to the value of savings over time for the long-term perspective of society or government.

The net benefits do not include the externality costs as part of this report. These costs will be added later. For some options, such as enhanced land use planning, the net benefit could not be determined due to the variety of non-energy costs associated with the option and the unknown value of changes in utility for the traveler due to land use policies.

Where possible, results have been expressed in terms of Direct Non-Environmental Net Benefits which consists of the sum of Direct Non-Environmental Net Consumer Benefits and Impact on Government Revenues as described below.

Net Consumer Benefits. An important economic metric to gauge and compare the societal value of different actions that affect the market place is the resultant change in net consumer benefits (also known as consumer surplus). The concept of consumer surplus is explained in detail in the Group 3 Methodology section (see below). In simple terms, the difference between a consumer's maximum willingness-to-pay and the market price of a good is described as net consumer benefits. When consumers face a lower (or higher) price for some good, the consumer surplus associated with that good increases (or decreases).

On the producer side, there is an analogous measure of net benefits, known as producer surplus. If the price received by sellers changes, producer welfare is affected (producer surplus will increase or decrease, depending on the direction of the price change). As an example, if producers pay a fuel excise tax, and the full amount of the tax cannot be passed on to consumers, producers will receive a lower effective price (relative to no excise tax) and therefore suffer a loss in producer surplus.

In this analysis however, staff assumed that the impact of any price change relative to base case assumptions is borne completely by consumers (that is, producer surplus is not affected). Staff assumed a higher gasoline excise tax (as in Option 3A) is passed on completely to consumers.[1] Similarly, a subsidy on vehicle purchase price reduces the amount paid by consumers by the full amount of the subsidy.

Impact on Government Revenues. The impact on government revenues is the sum of any increases in consumer costs that are borne by government and any change in excise tax collection. For example, a consumer education campaign to reduce fuel use by providing information might to be implemented using government funds. The impact on government revenue would be the sum of the amount expended for the campaign and the loss of reduced fuel excise taxes.

Since ethanol receives a federal subsidy of approximately 52 cents per gallon of ethanol when blended into gasoline, any reduction in gasoline demand would reduce federal revenue needed to pay the subsidy. This effect was also included in the calculation of government revenues.

If an option employs a government incentive to reduce direct consumer cost, the incentive amount is considered to be a government revenue loss since this amount is no longer available to produce other benefits. It would be equivalent to a reduced revenue flow.

Deadweight Losses. In Option 3F (Purchase Incentives for Efficient Vehicles) the amount of government revenue spent on the subsidy exceeds the benefit that the incentive provides buyers of these vehicles. The difference between the two is a welfare, or deadweight loss.

This accounting is somewhat incomplete however, since the ultimate net impact of a subsidy on consumer welfare in California will depend to a certain degree on how the subsidy is funded. For example, if the subsidy were funded by a reduction in or elimination of some other subsidy, a deadweight loss elsewhere in the economy would be reduced or eliminated.

On the other hand, if the incentive were funded by a tax increase, an additional deadweight loss could be created. It is also possible that the penetration levels induced by the subsidy could be achieved by a regulation or mandate that would apply to commercial fleet owners, so that no incentive would be required. This would still create a welfare loss for fleet owners, however, and there is no reason to believe that this loss would be any smaller than a subsidy deadweight loss.

Discount Rate. Staff used a 5 percent discount rate to calculate net present value.

Step 5. Use Common Metrics for Comparison

Staff used a cost-benefit framework to measure, evaluate and compare the value of different petroleum reduction options, using validated and uniform inputs whenever possible. Each option was compared against base case conditions to derive cost-benefit metrics, including:

A. Net consumer benefits (includes value of fuel savings) except for Group 2 as explained below.

B. The impact on government revenues (taxes, fuel subsidy, program costs).

Using these values and the analysis performed in Steps 1 through 4 above, staff then determined the net direct benefits (the difference between A and B above) to society (not including the environmental benefits).

Staff derived additional economic outputs by taking the annual net consumer benefit, the annual change in government revenue, and the annual net benefit in a specific year and dividing by the corresponding annual fuel displacement. This calculation allows an option to be gauged by the amount of consumer savings (a positive net consumer benefit) or cost (a negative net consumer benefit) per gallon of fuel displaced. Options produced greater consumer savings per gallon of fuel displaced are preferred.

Groupings and Placement of Petroleum Reduction Options for Comparisons

With the exception of Option 1F (Light-Duty Diesel Vehicles) the petroleum reduction options have primarily been grouped by the methodology used to in its evaluation and by its mechanism for reducing the demand for petroleum fuel. This allows for useful comparisons among the options in a group. Some options rely on improved energy efficiency to reduce fuel use. Other options substitute a petroleum fuel with a non-petroleum fuel. A third grouping results from using pricing schemes to change consumer choice or product offerings to reduce fuel consumption.

The Light-Duty Diesel Vehicle case is both an energy efficiency opportunity (Group 1) and a fuel substitution option (Group 2) and its placement in either group is possible. A diesel vehicle can substitute for a gasoline vehicle and thus reduce gasoline demand. Nevertheless, the staff has chosen to insert the Light-Duty Diesel Vehicle option in Group 1. This result comes from the staff's belief that with advances in emission control technology, diesel engines can significantly contribute to an increase in an auto manufacturer's corporate average fuel economy rating. The attractiveness of the diesel option to manufacturers and consumers, in part, will be its greater fuel economy compared to an equivalent gasoline vehicle. This attribute links the light-duty diesel option to some of the other technology packages examined in Option 1A (Improved Vehicle Fuel Economy). Because of data limitations, however, the methodology used to evaluate Option 1F is different from that used for Option 1A.

GROUP 1 METHODOLOGY

The fuel efficiency category uses scenarios created from data on current market characteristics. Each of these options uses an estimated change in consumer behavior due to a specific stimulus or imposed conditions. The change in behavior would result in a reduction of petroleum fuel use. The estimated fraction of consumers who would react favorably to the stimulus and other analytic parameters determine the potential fuel displacement and economic outcome of the option.

In the scenarios for the fuel efficiency options, net consumer benefits are the summation of monetary flows resulting from consumer credits (e.g., fuel savings would be a positive flow) and debits (e.g., incremental higher purchase price for a required product would be a negative flow).

Consumer Education and Outreach. Some of the options being evaluated to reduce the use of petroleum fuels assume that consumers will act to use less transportation energy if they have access to information on the energy implications of these options compared to other market choices. The analysis assumes information would be provided through a public education and media campaign that results in a reduction of energy consumption compared to the base case.

The effectiveness of the campaign would then help calculate the amount of fuel reduction that might be achieved with a particular option.

Estimates for the cost of the campaign and potential effectiveness are gauged from previous public education campaigns. These campaigns are described in Table A-1. However, actual results from a public education campaign are highly dependent on the complexity of the subject matter, remembering the message when an opportunity to act arises, and the ease or difficulty of taking action.

The media campaigns focus on achieving consumer awareness to the issues of interest. Various response attributes are then measured through consumer surveys after exposure to the campaign. The campaign effort and cost include development of the consumer message, distribution of the message, and evaluation of the campaign.

The options relying upon a media campaign are Option 1B (Fuel Efficient Replacement Tires and Tire Inflation) and Option 1D (Vehicle Maintenance Practices). The annual campaign cost used in the economic analyses for each option is $10 million. This expense is comparable to the statewide examples (or statewide extrapolated estimates) displayed in Table A-1. The campaign is assumed to influence 30 percent of the pertinent population of consumers. The potential consumer response is within the range of results directly attributable to the campaigns listed in the table, as well.

Table A-1. Examples of Media Campaigns

Media Campaign	Annual Expenditure, $	Media Methods	Consumer Results, %	
			Awareness	Response
"Spare the Air Campaign"; JHME, Carol Johnson; Sacramento regional campaign on air quality; episodic application when air quality conditions warrant decreasing air pollution	$3.5 million (estimated $5 million statewide)	advertising and public relations; radio, TV, internet	75%	6-8% drove less
"Give Your Appliances the Afternoon Off Campaign"; Southern California Edison	$1.6 million (1980s $) (estimated $10 million statewide today)	radio, TV, print	86%	75% of those aware acted to reduce load; 40% of those aware were influenced by ad to act
Recycling Campaign for New Containers[a]; California Department of Conservation, Division of Recycling; increase awareness of new recyclables	$10 million (2000-01)	radio, TV, outdoor messages, internet	64% recall media messages (55% pre-wave)	80% of households recycle[b]

[a]2001 Year End Report, Marketing and Media Campaign Summary, Riester-Robb for the California Department of Conservation, Division of Recycling, June 2002.

[b]The measured response is not solely attributable to the 2000-2001 campaign since 55% of those surveyed were aware of recycling prior to the specific campaign. Unaided usage of curbside and staffed parking lot recycling locations increased by about 28 percent over pre-wave values.

The sensitivity of the results for projected reduction in fuel use and cost-benefit was examined by arbitrarily increasing the cost to $20 million and decreasing the fraction of influence to 15 percent of the targeted population. The cost-benefit results were significantly more sensitive to the percentage of the target population influenced by the campaign than by the annual amount expended for the campaign. A much larger fraction of the monetary flows originates from reduced collection of excise taxes than from expenditures for a media campaign.

GROUP 2 METHODOLOGY

Those options included in Group 2 (Fuel Substitution) required a slightly varied approach from the general methodology due to the inherent differences in their market status. Because each technology in that group is at a different point of development, both the timing and the likelihood of meeting development program goals for cost and performance varies for each option.

In order to compare them, staff evaluated each option at some point in time when it has reached a "mature market" condition. Where possible, staff assessed the level of research and development funding needed to make the technology mature. Staff also provided an estimate of the status of development where possible. In addition, staff assumed that if a technology reaches a mature market condition, it would do so no later than the year 2030.

The cost to develop the technology is not separately accounted for in the analysis. This is because staff expects incremental vehicle costs to include any private monies spent on R&D. Also, information on the cost of developing each option's technology is generally not publicly available.

For all of the fuel substitution options, net consumer benefits are calculated in a manner similar to the fuel efficiency scenarios. In the event that the net consumer benefit is negative, the consumer is not better off and would not likely change their behavior voluntarily. If an option produces a negative consumer benefit and yet other policy considerations make it desirable for deployment, an implementation strategy would have to be adopted to overcome the negative benefit. In a market-based approached, the consumer must at least be made indifferent to the option compared to the base case outcome in order for the option to gain market share. The strategy must provide the consumer with real or perceived additional benefits not yet included or apparent in the current cost-benefit result, sufficient in magnitude to make the net consumer benefit positive.

When an implementation strategy is required to overcome what might otherwise be a negative net consumer benefit, the specific strategy that might be adopted will effect the cost-benefit result. Different cost-benefit conclusions will result for different strategies. For example, if the strategy employs a direct monetary contribution as a consumer incentive to achieve a positive net consumer benefit, the resulting net consumer benefit will depend on the incentive mechanism, as well as, the incentive amount. In this example a range of positive benefits would flow to consumers (zero for some and up to the incentive amount for others), changing the consumer benefit total in a positive direction. However, a market inefficiency, described as a deadweight loss, would be created that would have a negative effect on the existing net benefit value (see the discussion in the Consumer Surplus section for additional detail). Thus, estimating the magnitude of cost-benefit change resulting from an implementation strategy is case specific and not a trivial calculation.

Where an option does not have a specific implementation strategy as an inherent condition for the option, the staff has not attempted to define strategies to overcome a negative consumer benefit outcome and to then bound the cost-benefit results. Such an effort exceeds the current time and resources allocated to produce usable results.

Nevertheless, significant market penetration is uniformly assumed for the fuel substitution options even though some of these options may not project positive net consumer benefits. The penetration assumption allows the use of estimates for mature product costs and economies of scale. The resulting consumer and net benefit results are useful for screening purposes and as comparison values among the fuel substitution options but not as predictions of absolute consumer or net benefit values.

Gasoline and Diesel Fuel Displacement. Staff assumed that most of the options will be sufficiently mature to reach 4 percent of new vehicle sales by 2010 and 10 percent by 2020. This non-linear ramp-up to a 10 percent market penetration was selected as a reasonable upper bound based upon historical efforts to introduce alternative fuel technologies. For those option technologies that need a longer period of time to reach the mature market condition, staff assumed they reach 4 percent market penetration by 2020 and 10 percent by 2030. Staff also assumed that this level of penetration in annual new vehicle sales is sufficient to capture economies of scale and allow the use of mature incremental unit costs employed in the analyses.

Actual market penetration of the Group 2 options will depend on the performance and price of the vehicles when considered by consumers. If an option provides net consumer benefits that are sufficiently high, its market penetration may be equal to or greater than 10 percent or vice versa. If more than one option reaches a mature market condition, the amount of gasoline or diesel displaced will be less than the sum of the two assuming they displace the same conventional fuel. This effect occurs because the options would each take a portion of the other's market, in essence, competing against each other rather than the conventional gasoline or diesel fuel. Where possible, a discussion of factors that may influence the pace of this market maturing process is included.

Economic Comparisons. Each of the options in Group 2 (and Option 1E) used a series of spreadsheets to calculate the effect of discounting future costs and savings (Present Value). The results of these spreadsheets are presented in this report in Attachment B as a "Summary Sheet" for each option.[2] Each summary sheet is divided into two major areas: (1) Major Input Assumptions (on the right-hand side) and (2) Results of the Analysis (on the left-hand side).

Although the staff assumed that each of the Group 2 options could achieve a 10 percent market penetration in new vehicle sales for comparison purposes, specific deployment strategies that might be required to reach this penetration level have not been evaluated. If market-based scenarios were to be created with sufficient confidence and detail, staff could then make a reasonable estimate of the option's economic outcomes, including the effects of the strategy, using the methodology previously described.

1. Major Input Assumptions

For Conventional Vehicles:

- **Fuel Economy.** For conventional light-duty gasoline vehicles, we assume an average fuel economy of 21.2 miles per gallon, consistent with our base case forecast. For light-duty diesel vehicles, we assume a 45 percent improvement in miles per gallon compared to the average gasoline vehicle, or 30.7 miles per gallon of diesel.

- **High and Low Fuel Price Estimate.** Projected long-term gasoline fuel prices are constant at $1.64 per gallon, with a range of $1.47 to $1.81 per gallon (in 2001 dollars) to reflect the mean price plus and minus one standard deviation based upon historical price fluctuations. Corresponding diesel prices are $1.65 per gallon with a range of $1.48 to $1.82 per gallon.

For Each Option:

For the technology analyzed in each option, we assume the fuel economy, incremental capital cost, and projected fuel price range specific to the technology. Refer to the discussion of each option for more information on its assumptions.

- **Vehicle Fuel Economy.** Refer to the discussion in each option for more information on these assumptions.

- **High and Low Incremental Capital Cost.** The option's capital cost is shown relative to the cost of the conventional vehicle it would replace.

- **High and Low Fuel Price.** The option's fuel cost is determined as follows. First, the wholesale price is determined by using historical data to find the "Sale to Resellers" or some other wholesale price. For example, the Sale to Resellers price is available for LPG, as a national average, from the U.S. Department of Energy's Energy Information Administration web site.[3]

  First, staff derived the average wholesale price and one standard deviation. This yields a "high" and "low" fuel price range. Then staff assumed this price range can be used to represent future wholesale costs. This is done to be consistent with our gasoline and diesel future price forecasts where staff assumed essentially flat gasoline and diesel wholesale prices over the time period.

  For LPG, staff assumed that sufficient additional volumes could be made available for an additional price of 15 cents per gallon, to "bid it away" from traditional industrial users in the Gulf Coast and transport it to California. Then staff assumed that the dealer receives the same price mark-up per gallon as gasoline, another 15 cents per gallon. Finally, staff assumed that existing excise and sales taxes are added to determine the retail price.[4] See Option 2E discussion for more details.

- **Vehicle Life.** For light-duty vehicles, staff assumed a 15-year vehicle life, with 16,500 miles per year in the first year of operation and usage decreasing as the vehicles age, reaching 5,764 miles per year by the 15th year, for a total of 147,308 miles over the vehicle life. These assumptions are consistent with CALCARS. For heavy-duty vehicles, staff assumed a 16-year vehicle life and annual mileage that varies by type of vehicle.

- **Discount Rate.** As noted above, staff used a 5 percent discount rate to calculate net present value.

- **Option's Vehicle Deployment.** Staff determined a vehicle deployment rate needed to ramp up to 10 percent new vehicle sales (see discussion below).[5] Each option's summary table contains a deployment graph showing annual vehicle sales, fuel displaced and cumulative vehicles sold.

2. Analysis Results

Staff provides results with a range of outputs. Staff calculated a range of fuel prices from the expected mean price plus and minus one standard deviation. Staff determined one end of this range by assuming high option fuel and capital costs and determined the other end of this range by assuming low option fuel and capital costs. The results of the analysis are shown on the Summary Sheet for the three time periods.

Present Value Million 2001 Dollars Saved Over Time Period. Results are first shown as present value dollars (2001 dollars) as a range of expected Net Consumer Benefits, Change in Government Taxes, and the Net Benefits (see definitions for these columns below).

Conventional Fuel Displaced. This column shows results in terms of cumulative million gallons of conventional fuel displaced over the same time periods and in specific target years (2010, 2020 and 2030).

2001 Dollars Per Gallon of Conventional Fuel Displaced. For target years 2010, 2020 and 2030, the table shows the benefits (savings or costs) for that year (not in present value terms) divided by the gallons displaced in that same year. Positive values represent savings and negative values (in parentheses) represent costs, both in dollars and dollars per gallon.

- **Net Consumer Benefits.** As described above, staff compared high fuel and incremental capital costs at one end of the range and low fuel and capital costs at the other end of the range. For easy comparison, staff subtracted the fuel savings (or costs) from the annualized capital cost to determine net consumer benefits per vehicle. Incremental capital costs were annualized using the 5 percent discount rate, a 15 year vehicle life (16 years for heavy-duty vehicles), and payment at the beginning of each year.

A negative fuel savings represents the case when the alternative fuel vehicle's annual fuel cost is higher than the cost of fuel for the conventional vehicle and may result in the Net Annual Savings becoming negative. This result is expressed in parentheses to reflect the negative value. Annual fuel savings (or costs) decrease annually during the 15 years of vehicle life as the vehicle is driven less each year it ages.

- **Change in Government Taxes.** Existing taxing requirements and the federal ethanol subsidy were assumed to remain throughout the 2002 to 2030 time period, although significant non-petroleum fuel use could cause these tax requirements to change in ways we cannot anticipate at this time.

- **Net Benefits.** A combination of the "Net Consumer Benefits" column and the "Change in Government Taxes" column.

GROUP 3 METHODOLOGY

The Commission's CALCARS model was used to simulate the options in Group 3. CALCARS is a behaviorally-based vehicle choice, usage, and demand model estimated specifically for California. The model predicts at the household level, using 57 types of households that vary by annual income, number of members, and number of employed members.

The CALCARS model operates under a basic economic concept that consumers will maximize their utility (self-interest or receipt of benefits provided by a product or service) when choosing goods and services, subject to market prices and their ability or willingness to pay those prices. In general, however, sellers of goods and services cannot isolate each consumer and charge the maximum he or she would be willing to pay. Typically, the seller establishes a price that is usually less than this maximum.

Such market behavior favors the consumer because they will generally pay a price that is less than what they were prepared to pay. From the consumer's viewpoint, consumers receive some benefits that they valued but do not have to pay for; the money that would have been spent due to a higher price can now be used to acquire other benefits. The value of this additional benefit can be called a surplus, and it is an inherent part of the total benefits received by a consumer.

The present value of net consumer benefits and any subsidy or revenues associated with the measure can be derived from the numerical results predicted by CALCARS. The net consumer benefits value includes specific vehicle attributes addressed by the model, including fuel cost per mile and vehicle cost to enable the value of fuel savings and other changes in utility to the consumer to be measured.

The total direct net benefits for an option are the net consumer benefits plus associated tax revenues minus state subsidies, if any, for the option. While vehicle class size is included, vehicle weight change that may be important for fuel economy measures is not addressed in the model analysis. The CALCARS model was used to develop the base case forecast and to evaluate the cost-benefit of pricing options.

The single pricing option that used a non-CALCARS framework employs a scenario with a monetary incentive to selectively reduce the purchase price of more efficient vehicles currently marketed. The net consumer benefit in this scenario is solely dependent on the magnitude of the incentive provided to the consumer. The value of fuel savings produced by the more efficient vehicle would be an inherent portion of the net consumer benefit created by the incentive and would not be considered an additional consumer benefit to be added to the incentive amount. Without the incentive, the consumer would have purchased a less efficient vehicle that he valued more than the "efficient" vehicle and its related fuel savings. In the economic comparison between these two choices, one with an incentive and one without, the net consumer benefit is no greater than the incentive amount.

Free riders are those consumers who would have purchased the more fuel-efficient vehicle without the incentive but who receive a benefit equal to the full value of the incentive. If the demand curve is linear, consumers who decide to purchase a more fuel-efficient vehicle due to the incentive receive a benefit that is estimated to be one-half of the incentive amount (see detailed discussion in the Consumer Surplus discussion below). For these latter transactions, one-half of the incentive amount equals the deadweight loss.

Impact of Improvements in Fuel Efficiency on VMT. One of the parameters used in staff's analysis of petroleum reduction options is the price elasticity of vehicle miles traveled (VMT) with respect to changes in fuel cost per mile. Staff examined a number of empirical studies in an attempt to arrive at an estimated price elasticity value. Most of the studies, however, did not specifically measure the consumer's response that might result from purchasing and driving more fuel efficient vehicles, or vehicles that use alternative fuels. In addition, the range of elasticity values reviewed varied considerably and the joint ARB/CEC staff team could not find consensus on a value to use in the analysis. As a result, the joint staff team has concluded that further research is needed to determine appropriate elasticity applications for fuel efficiency and alternative fuel options.

Consumer Surplus. Since it is not possible for sellers of automobiles (or most other goods) to isolate every buyer and charge the maximum he or she would be willing to pay, the purchase price of an auto will usually be less than the total benefit to the buyer. The difference between a consumer's maximum willingness to pay and the market price of a good is known as consumer surplus. Since consumer surplus is a part of the total benefit of vehicle ownership and use, changes in consumer surplus that result from implementation of new transportation measures must be considered in any cost-benefit analysis of these measures. The concept of consumer surplus is used extensively in economic analyses, primarily in studies that deal with consumer welfare.

To understand consumer surplus, the place to begin is with the concept of demand. The Law of Demand states that if a good is normal (that is, the demand for that good rises when income increases), the amount demanded of the good will fall when its price rises. Put another way, a normal good will have a downward sloping demand curve.

Table A-2 displays an example of an individual's demand for a normal good ("widgets") at various prices. At a price of $8, the consumer will not buy any widgets, at $7 he will buy one, and so on. Now suppose that the market price is $5, which means that the individual will buy three widgets. However, as the demand schedule shows, he would have paid as much as $7 for the first unit (i.e., the first unit has a value of $7 for this consumer). The difference between the value of the first unit to the consumer, $7, and what he actually pays, $5, is a gain from trade, or consumer surplus, of $2. Similarly, the second unit yields $1 of surplus, for a total of $3. Although not as tangible as a gift of $3, this benefit is just as real. Total consumer surplus would rise if the going price of widgets dropped and fall if the price rose (e.g., a price of $4 yields $6 in surplus and a price of $6 yields $1). If a tax of $1 were placed on this good when the price was $5 (so that the price became $6), consumer surplus would fall by $2.

Table A-2. Demand for Widgets

Price ($)	Amount Demanded
8	0
7	1
6	2
5	3
4	4
3	5
2	6
1	7

Economists associate a level of satisfaction, or utility, with the consumption of a good or service. A basic tenet underlying demand curves is that consumers maximize their utility when choosing goods and services, subject to market prices and income or wealth. This means that a consumer's demand curve for a product is the direct result of utility maximization. Using the example given above, utility maximization leads the consumer to demand two units when the price of widgets is $6, to demand three units at $5, and so on.

In order to model consumer preferences, the utility function is used. This function assigns a number to every possible consumption bundle (combination of goods and services) under consideration, so that more preferred bundles are assigned higher numbers than less preferred bundles. Demand for a good or service can then be derived from the utility function, maximized given prices and income or wealth.

In the CALCARS model, households choose vehicles based on the utility that they offer, where utility is a function of fuel cost per mile, performance, size class, etc. Since consumer surplus can be estimated from an individual's demand curve, and demand can be derived from a utility function, it follows that consumer surplus can be estimated directly from a utility function. This is the approach used in the CALCARS consumer surplus calculations.

The following discussion illustrates the net costs imposed on society of both incentives and taxes. It should be noted that these results do not mean that taxes and incentives are never justifiable from a societal perspective. For example, subsidies may be justified in terms of accelerating the development of a new technology, and taxes may improve societal welfare if the good being taxed generates external (environmental) costs.

- **Incentives.** If the government takes money from a taxpayer and gives it to someone else, there is no net effect on direct costs/benefits. However, if the government takes money from a taxpayer and gives it to someone else conditional on purchasing some product (i.e., an incentive), then there can be a net effect.

  Suppose the government offers an incentive of $1,000 to purchasers of natural gas vehicles (NGVs). This is shown in Figure A-1, assuming a linear demand.

  Q_1 is the amount of NGVs purchased before any incentive, at price p_1. Q_2 is the amount of vehicles purchased with the incentive. The cost of the incentive is \$1,000 × Q_2. However, the benefits (the increase in consumer surplus going to buyers of NGVs) are only (\$1,000 × Q_1) + (\$1,000 × ($Q_2 - Q_1$)/2), which are less than the costs. In the graph, the area shaded with vertical lines (the increase in consumer surplus) gives the benefits. The net cost of the incentive (known as the "deadweight" loss) is shown as the triangle shaded with horizontal lines.

  Intuitively, the reason that benefits are less than costs is that the benefit to buyers that would not have bought the NGVs without the incentive is less than $1,000 per vehicle. For example, there may be a new vehicle purchaser who values a gasoline vehicle at $600 more

Figure A-1. The Net Costs of an Incentive for Natural Gas Vehicles

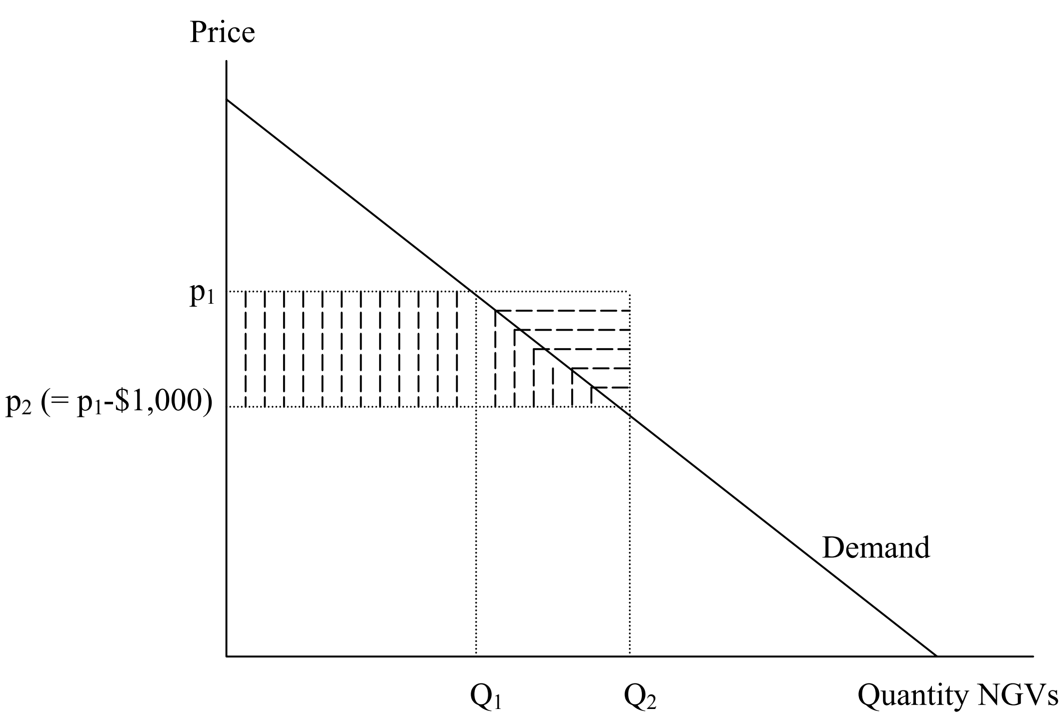
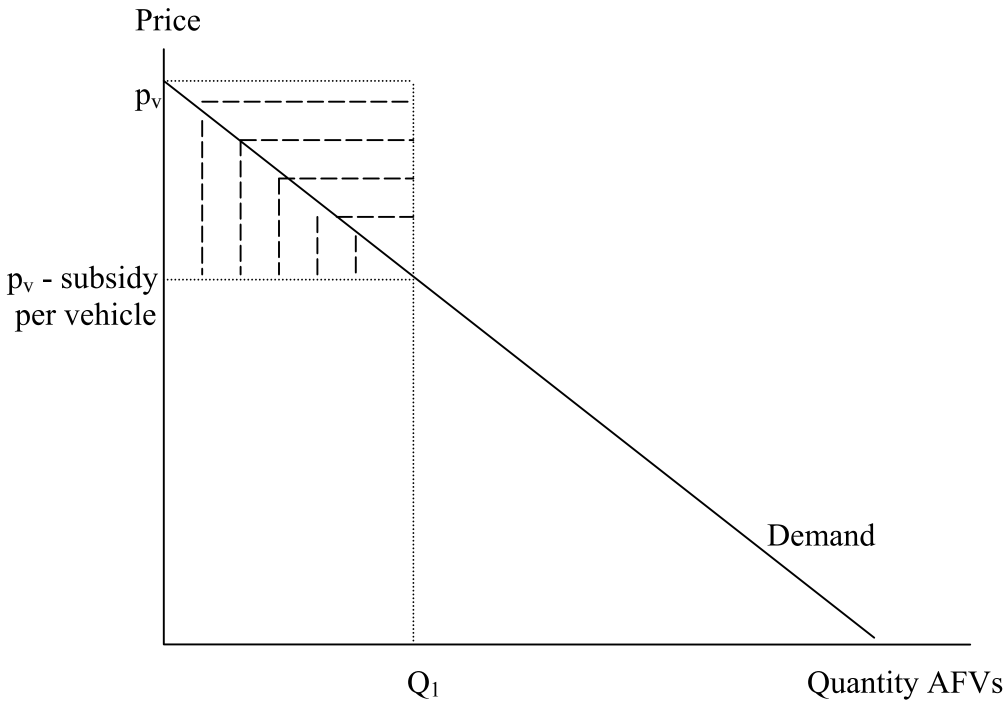


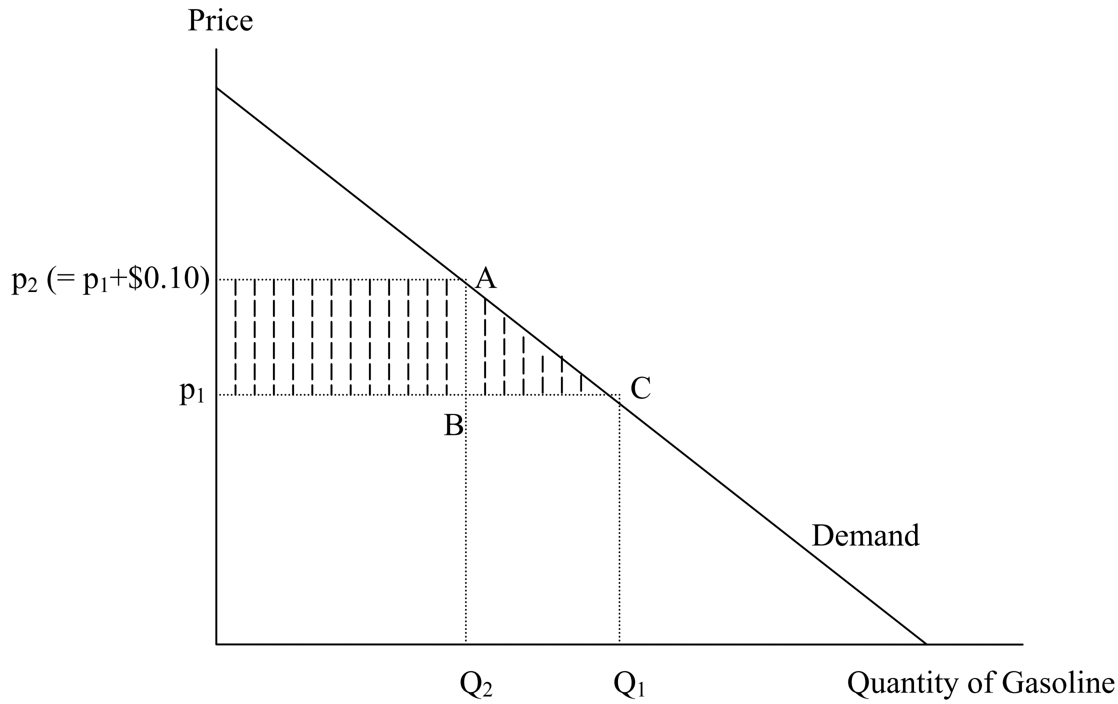
Figure A-2: The Net Costs of an Incentive for Alternative Fuel Vehicles Assuming Negligible Initial Demand



than a similar NGV so that, without any incentive, this buyer would choose the gasoline vehicle. If an incentive of $1,000 were offered for the purchase of an NGV, our buyer would now choose the NGV, since the net benefits corresponding to this vehicle are now higher than those of the gasoline vehicle. However, the buyer is only $400 better off than he would be with the gasoline vehicle ($1,000-$600). In other words, this transaction results in a net cost to society of $600, since we have spent $1,000 to yield a benefit of only $400. The total net costs of this incentive come from all buyers who would require less than $1,000 to switch. The only way that we could make the net costs of this incentive zero is if we could individualize the incentive--paying each person just what it would require for them to switch. Unfortunately, this would be almost impossible to do.

Some of the measures included in Group 2 involve cases where there is a projected net cost (that is, the net impact of differences in capital costs and fuel costs is greater than zero) to owning and operating an alternative fuel vehicle relative to conventional gasoline. In these cases, it is assumed that a purchase price subsidy is offered to compensate for the difference. Such cases represent a slight variation on the discussion above. Assuming that sales of such vehicles are negligible before the subsidy is offered, the movement along the demand curve due to the subsidy would begin at its vertical intercept, corresponding to price p_v in Figure A-2. The subsidy reduces the purchase price and brings the amount demanded up to Q_1. The increase in consumer surplus is given by the area shaded with vertical lines, and the total subsidy paid is the amount of the subsidy per vehicle times Q_1. Therefore, the net cost of the incentive (the deadweight loss) is shown as the triangle shaded with horizontal lines (equal to one-half of the total subsidy paid).

Figure A-3. The Net Costs of a Gasoline Tax



- **Taxes.** The net cost to society of a tax (such as an excise tax on gasoline) is the difference between the loss in consumer surplus due to the tax and the tax revenue that is generated. Suppose that an excise tax of 10 cents is placed on the price of gasoline (or, more realistically, the excise tax is raised by 10 cents). Figure A-3 shows the result.

  Q_1 is the amount of gasoline purchased before the tax, at price p_1. Q_2 is the amount of gasoline purchased with the tax imposed, at the higher price p_2. The tax revenue generated is the amount $(p_2 - p_1) \times Q_2$, which would be considered a benefit to society. However, the cost of the tax--the loss in consumer surplus--is the entire shaded area shown in Figure A-3. Therefore, the tax imposes net costs on society (known as the "deadweight" loss), given by the triangle ABC. Intuitively, these costs are the value to vehicle owners of the reduced consumption of gasoline.

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[1] In economic terminology, we would say that the supply curve for producers is flat.

[2] For electronic copies of these spreadsheets, please call the Transportation Technology Office or see the Energy Commission's web site at http://www.energy.ca.gov/fuels/petroleum_dependence.

[3] http://www.eia.doe.gov.

[4] For electricity and natural gas, the methodology is essentially the same, except we use Energy Commission forecasted commercial end use prices for each service area to determine the high and low price range. For electricity, we assume that off-peaking charging costs 60 percent of the average rate. For natural gas, we assume an additional 32 cents per therm of natural gas dispensed, based upon commission contract experiences. This covers

O&M, electricity for running the compressors, labor, etc. (References: CEC price forecast reports and Transportation Technology Office program data.)

[5] Staff assumed a nominal 4 percent displacement of conventional fuel by 2010 and 10 percent by 2020 (Options 2D, 2E, 2F, 2G, 2H, 2I and 2J). For the remaining options (2A, 2B and 2C), staff assumed the 4 percent displacement value is reached in 2020 and the 10 percent value is reached by 2030.